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INSIDE IRAN'S ENRICHMENT PLANS

SECURITY IN THE USA

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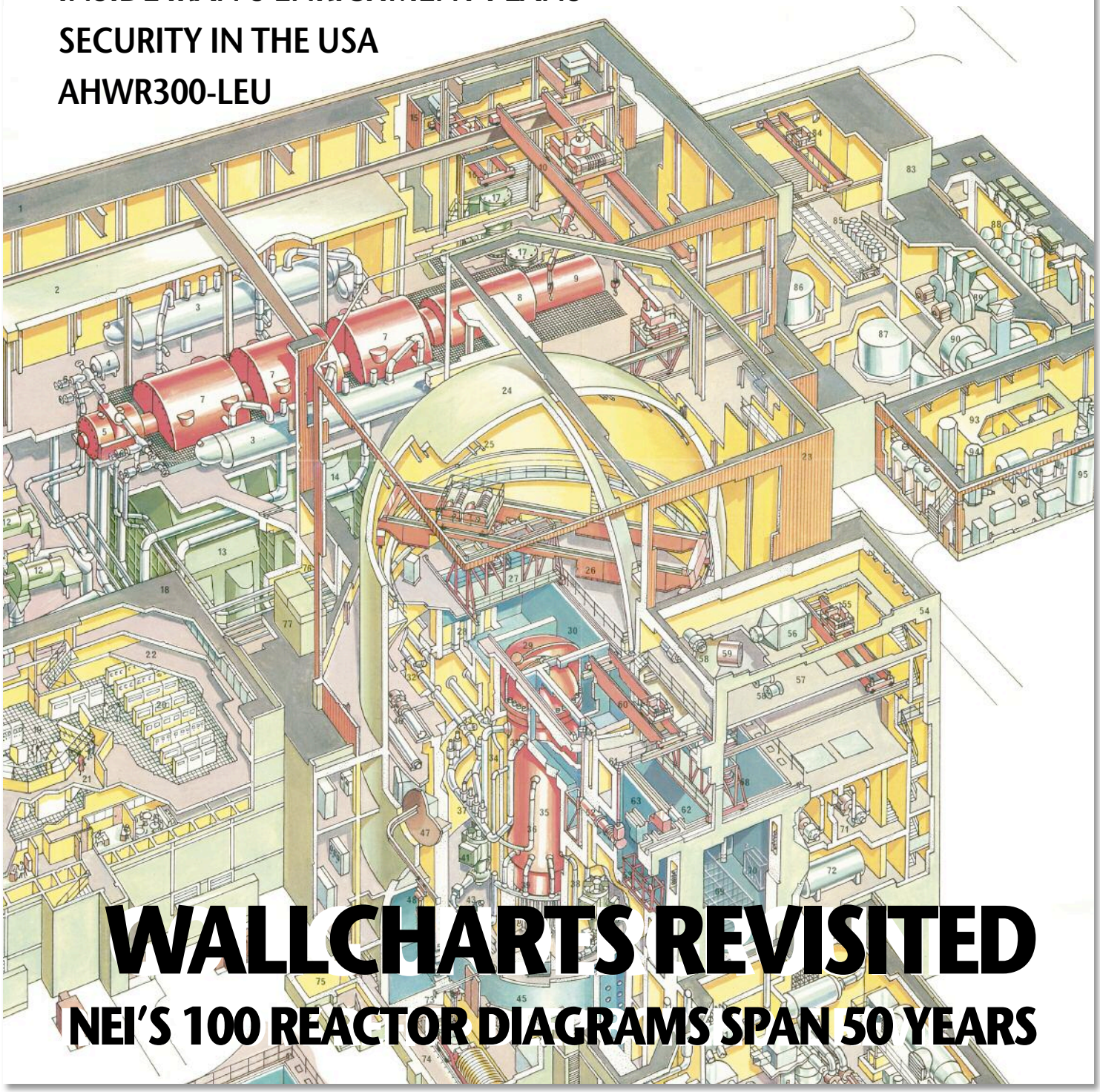

WALLCHARTS REVISITED

NEI'S 100 REACTOR DIAGRAMS SPAN 50 YEARS

X-ray machines: when is a nuclear power plant like an aeroport?

The x-ray scanners at the entrance to French nuclear power plants are very similar to those used in aeroports, according to Guillaume Auffret, sales manager for machine vendor Hightech Detection Systems. Queues build up behind them three times a day during shift changes.

And like an aeroport, the x-ray machine verifies that personnel are not carrying contraband. "You can go on to an aircraft with tools, you just have to announce it. It is exactly the same situation for power plants," Auffret says.

In 2009, HTDS won a fixed-price global contract with EDF to replace all of its machines. The machines are between 12-14 years old. The order is for a minimum of 55-60 machines, including an initial 20 emergency replacements at undisclosed locations. HTDS typically installs 3-4 units of its small parcel model 620 at an entrance, and a single larger unit for bigger packages. HTDS also trains the security personnel, employed by subcontractors, who operate the machines. Typical training courses run from between 2-5 days and include training on simulators.

However, even training is not necessarily enough, Auffret says: "They need to have imaging training, and they have to be interested in that. If someone wants to see nothing, they will see nothing. The machine only supplies images; the decision is taken by a human."

The industry responds

Utilities respond to specific criticisms raised by Lyman.

Dominion

"Prior to the September 11, 2001, terrorist attacks in New York and Washington, our nuclear stations were hardened facilities and protected by a highly trained security force. Following the attacks, more attention was focussed by the federal government on increasing nuclear security to higher levels, and new orders were being issued by the Nuclear Regulatory Commission. Our nuclear security program at Millstone met all of the federal requirements to protect the station from an hostile action by an adversary and, like the industry, we were adding additional defences to ensure greater fortification of our facilities. When Homeland Security offered to provide us with a waterborne barrier device, we determined that it would have minimal impact in protecting the station, so we opted not to accept it."

Tennessee Valley Authority

"The TVA's nuclear plants were well protected before 9/11 and are more secure today than ever before. TVA and the industry moved immediately after the 9/11 attacks to harden security with manpower, equipment and infrastructure at nuclear plants and other facilities. Efforts to further bolster security are continuing with additional security upgrades.

"Security requirements issued by the Nuclear Regulatory Commission after 9/11 have been met at the TVA nuclear plants and the fluid nature of potential threats are continually addressed through information exchange and training. TVA is implementing the security updates that the NRC issued in May 2009 and a number of these updates will be completed by the implementation date of 31 March 2010.

"Like numerous other U.S. nuclear utilities, TVA requires additional time to completely implement certain elements of these security updates. TVA's extension request ensures that any unforeseeable delays would not require another extension."

EDITOR'S NOTE: A response from the Nuclear Energy Institute will be published in the next issue.

out of 24 FOF inspections conducted in 2008, the latest year for which data is available, there were two failures of armed security personnel to protect target sets. This is a failure rate of about 10%, assuming that the two failures occurred at different sites. While better than a failure rate of 50%, anything greater than zero is arguably still too high, given the potential consequences of such a failure.

However, the FOF failure rate alone paints an overly rosy picture of the overall security posture at nuclear plants. This is because some plants may only just barely succeed, a fact that is not visible in the grading system. Such performance is problematic because in the event of a real attack with beyond-design-basis elements, the plant defensive strategy may not have sufficient margin to withstand the more severe challenge. To more precisely reflect plant security performance, the NRC staff began developing a proposal in 2009 to develop a more detailed security grading system that would also take into account margin to failure and other related issues. It remains to be seen whether industry will accept this change without objection, as some grades are likely to be lower under the new system.

Many other aspects of security are not captured by FOF inspections. One of these is fatigue. After the September 11 attacks, licensees sought to meet greater short-term security demand largely through increased overtime of the existing security officers, some working up to six 12-hour shifts a week. This interim approach eventually became the norm as managers remained reluctant to hire and train larger numbers of new security personnel in the face of an uncertain threat, leading to exhaustion and damaged morale in many cases. Prodded by the non-profit Project on Government Oversight (POGO), which had collected numerous case studies of overworked security guards, the NRC eventually proposed a rule to limit working hours for security staff. But it took the NRC over five years to put meaningful limits into effect, and in the interim more evidence of fatigue problems emerged. In 2007, a whistleblower provided a TV station with footage of security officers sleeping on duty at Exelon's Peach Bottom plant in Pennsylvania, ultimately causing Exelon to fire Wackenhut Nuclear Services, the security contractor for Peach Bottom and its nine other nuclear plants.

The new restrictions that went into effect in 2008 would essentially limit security officers working 12-hour shifts to 48 hours per week under ordinary circumstances. However, higher limits for security outage periods and liberal waivers for emergencies reduce the beneficial effect of the new rules.

CONCLUSION

It remains to be seen whether the attempted aircraft bombing on Christmas Day 2009 represents the beginning of a new wave of threats by al-Qaeda against U.S. domestic infrastructure targets. If so, it is troubling to note that nuclear plants are still not fully prepared to defend against the last wave. The latest indication of this is a recent flurry of requests by nearly half of all U.S. nuclear plant licensees for exemptions from the 31 March 2010 deadline for compliance with NRC's new security rules. For instance, the Tennessee Valley Authority has asked for extensions of more than two years for its fleet. If NRC grants these requests, the tenth anniversary of the 11 September will come and go before all U.S. nuclear plants have completed the required security upgrades. Unless the industry stops its foot-dragging and works more efficiently with regulators to promptly increase security as needed, there is little hope that plant defences will be able to keep ahead of the rapidly evolving terrorist threat.

Edwin S. Lyman, senior staff scientist, Union of Concerned Scientists, 1825 K St. NW, Ste. 800, Washington, DC 20006-1232. Omitted references are on www.neimagazine.com/force

Figuring out Fordow

Iranian President Mahmoud Ahmadinejad visiting the Natanz enrichment plant in April 2008. Credit: Sipa Press/Rex Features

The revelation that Iran is building a new enrichment facility outside Qom was widely portrayed as proof of Tehran's nuclear weapons programme. But, what is the plant's capability and what does this mean? ***By Ivanka Barzashka and Ivan Oelrich***

On 25 September 2009 Western leaders accused Iran of building a new and secret uranium enrichment facility, now known as the Fordow Fuel Enrichment Plant, in a mountain near the holy city of Qom. Iran had announced the facility to the International Atomic Energy Agency (IAEA) just days before and, Tehran claimed, well in advance of what it sees as its legal obligations. Western governments contended that the characteristics of the Fordow plant were inconsistent with a commercial facility and, therefore, inconsistent with a peaceful nuclear programme.

Estimates of Fordow's capacity indicate that the situation is more complex than was first portrayed. According to design information recently submitted to the IAEA, Fordow will contain 3000 IR-1 centrifuges, the kind that are currently operating at the commercial Fuel Enrichment Plant at Natanz. Based on IR-1 performance so far, it is true that Fordow, as planned, does not make sense as a commercial uranium enrichment facility. But the plant by itself is too small for even a nuclear weapons programme.

Other strategic functions suggested by Iran, that Fordow will serve as a contingency plant to maintain enrichment in case Natanz were bombed or, according to a quasi-government website, that it may devalue and deter an attack altogether, are also undermined by the plant's low capacity.

Fordow makes sense only within a context of increased separative capacity, coming either from higher per machine performance or from more machines. Iran seems to have acknowledged this problem with plans for new facilities and intentions to install better quality centrifuge models, which it has been testing since 2008. Iran's declaration of plans to build ten new enrichment facilities has been widely prematurely dismissed in the West as little more than bravado, but it should be taken seriously. Fordow makes most sense as part of a network of similar facilities and has no logical justification with current design. Even this new announcement does not make Iranian intentions absolutely clear-cut: With increased capacity, the commercial, military and contingency justifications all become more plausible.

WHAT IS THE IR-1?

Assessments of Fordow's civilian or military capacity hinge on the performance of the IR-1, the only commercially operating centrifuge in Iran. These estimates have varied greatly, but IAEA reports now provide enough information to calculate the capacity of the IR-1 in actual use.

The IAEA accepts separative capacity as competition-sensitive, proprietary information that is legitimately protected, so it is not directly collected by IAEA inspectors. Iran has never published quantitative technical details of its centrifuges, except for a couple of statements by officials.

Past estimates of IR-1 separative capacity have ranged from 1.4 to 3 kg-SWU/year, which has proven to be 3-7 times higher than actually achieved performance. Given the lack of hard quantitative data, most Iran-

watchers have been forced to make guesses based on analogues with the Pakistani P-1 model and its assumed early European prototypes. There is little consensus on what those European analogues are (whether the G-1, M4, CNOR or SNOR) and their performance is imperfectly known as well. Most information we do have on these machines comes from anonymous sources, such as unnamed Urenco, IAEA, intelligence or government officials, with presumed access to classified or confidential industry data but with unascertainable credibility. There have been some calculations based on physical characteristics of the machine (obtained through analogy or from the author's estimates). Statements and interviews in the Iranian media on machine performance have dropped estimates to about 1.4 kg SWU/year. However, these lower estimates from Iranian officials need to be closely scrutinized because Iran views its nuclear programme as a symbol of national pride and has been known to embellish its nuclear achievements.

IR-1 PERFORMANCE

Centrifuges have been spinning at Natanz since 2003 and the agency publishes reports on their operation several times a year. However, the utility of hard data on actual IR-1 performance from IAEA onsite inspections has been overlooked. Current IR-1 performance at Natanz is the best estimate for near-term capacity at Fordow.

For material accountancy purposes, the IAEA records the degree of enrichment and amount of uranium hexafluoride that enters and leaves the cascades, as well as the number of operational centrifuges. Based on this information, we estimated the effective separative capacity of the IR-1 to be 0.44 kg-SWU per machine per year or 4 to 5 times less than the most widely-referenced values in the literature.

It has been no secret that Iran's centrifuges have been and are not operating up to par. In 2008, an IAEA report stated that the "throughput of the facility has been well below its declared design capacity." Individual IR-1s are still being tested at the pilot enrichment facility at Natanz, which indicates that Iran is still hoping to improve performance. Moreover, Iranian officials themselves have stated that they are not happy with IR-1 performance and hope to install new models at Fordow. The very high tails assay that Iran produces at Natanz is further tacit acknowledgement that their enrichment is inefficient and expensive.

The IAEA data applies only to the entire production of Natanz, not individual centrifuges. The facility production might be low because individual machines are performing poorly or they may be inefficiently linked into cascades or, most likely, both. Iran has said that A.Q. Khan's clandestine procurement network offered the drawings of a second centrifuge model (the basis of three new models Iran has been testing) as a compensation for supplying defective IR-1 parts; poor components may be another reason that Iran is having difficulties getting the machines up to speed. In addition, inter-stage mixing and hold up during cascade operation contribute to separative work losses. So the performance of 164 connected machines is less than 164 times the performance of an individual machine.

We have to keep in mind that the IAEA data do not give us any information on why the performance is low, simply that it is. Whatever the reason for the performance shortfall, Iran has been operating the IR-1 for 7 years now, so we do not believe these are technical problems that are likely to be fixed overnight, hence our assumption that Natanz performance will be a good short-term predictor of Fordow performance.

FORDOW'S POTENTIAL

If estimates of Iranian enrichment capacity as a whole have been overstated, then estimates of how long Iran might take to enrich enough uranium for a nuclear weapon have been overstated as well. Based on current centrifuge performance at Natanz, it would take Fordow's 3000 IR-1s close to a century to enrich a year's fuel load for an average 1000MWe reactor starting with natural uranium and using typical global industrial tails assay. Therefore, by itself, Fordow does not make sense for a commercial enrichment programme. This fact, along with Fordow's unusual location inside a tunnel in a mountain close to a Revolutionary Guard base equipped with air-defence systems, has been widely interpreted as sign of a military programme.

But Fordow's capacity is also too small to be well-suited for a military programme. It would take over 3.4 years to enrich an IAEA 'significant quantity,' that is, enough for the simplest atomic bomb, of highly-enriched uranium from natural uranium, which we consider far too long to be a viable break out option, even if Fordow had been intended to remain a clandestine facility. In a year, the facility could produce a 'significant quantity' of bomb-grade material from already enriched reactor-grade uranium.

In either case, Iran would have to overcome safeguards hurdles. The first option would require diverting uranium hexafluoride from the conversion plant at Esfahan or constructing a clandestine conversion facility. Considering Iran's poor track record of keeping nuclear activities secret, we believe the government is unlikely to pursue that option. In the second case, Iran would have to divert low-enriched uranium from Natanz. Given the long enrichment times needed at Fordow, the IAEA is highly certain to detect a diversion before Iran could enrich enough material for a even a single bomb.

ONE OF SEVERAL SITES?

Fordow can make sense only if capacity is increased or it is one of similar sites. The facility's current capacity is too small to make sense for either civil or military activity, therefore separative capacity needs to be increased. This can be achieved either by increasing per-machine performance or adding more machines.

Adding more machines at Fordow may be problematic if space is scarce,

Members of the Iranian delegation, including Ambassador Ali Asghar Soltanieh (centre), discuss the provision of nuclear fuel for the Tehran Research Reactor, in October 2009. Credit: Dean Calma/IAEA

Map of Iranian nuclear facilities. FEP- fuel enrichment plant; UCF- uranium conversion facility; TRR-Tehran research reactor; LWSCR-light water subcritical reactor; HWZPR-heavy water zero power reactor; GSCR- graphite subcriticial reactor. Source: IAEA

which might be expected in an underground tunnel. Centrifuge numbers could, however, be increased by constructing similar enrichment facilities at additional locations. In an article published in the *Bulletin of the Atomic Scientists* in November 2009, we speculated that Fordow is most likely one part of a network of similar facilities, which Iran could legally decide to construct in the near future.

Iran has indicated that it may pursue both options outlined above. It has reserved the right to install newer and better-performing centrifuge models as they become available. Tehran also declared that it will be constructing 10 additional enrichment plants – a plan that has been belittled by the West as unrealistic and simply an act of defiance. But it is a mistake to dismiss the claim, because with current capacity Fordow simply doesn't make much sense. Although Iran has refused to disclose details on the planned facilities, we believe that the plants will be similar to Fordow – small and buried to protect against attack, because otherwise it would be more efficient to simply increase capacity at Natanz.

Both authors are with the Federation of American Scientists. Ivanka Barzashka is a researcher for the federation's Strategic Security Program, specialising in Iran's nuclear capability and potential, and Ivan Oelrich is vice president of the same programme. Federation of American Scientists, 1725 DeSales Street, NW, 6th Floor, Washington, DC 20036, USA

Increased separative capacity increases the plausibility of civil, military, and strategic justifications for Fordow, but not by the same degree. Dispersing the new facilities, keeping them small and forgoing economies of scale, and hardening against air attack, will increase costs and at first glance seems to prove that the facilities have a military, not civil, mission. But perhaps not.

We must keep in mind that even if the Iranian programme were purely civil, it is definitely not commercial. Decisions are not being made by a company but by a government bureaucracy, which is less concerned with simple cost and profit calculations. Natanz's performance is disappointing to Iran. From a purely economic point of view, there is little doubt that it would be better to buy enrichment services on the international market. Tehran has decided that option is not reliable and has gone for independence. They must know this approach would be more expensive but were willing to pay the cost premium for strategic energy security reasons. In addition, Iran has staked enormous political prestige, both domestic and international, on their enrichment programme. So all economic arguments about the programme are suspect. In particular, just because something does not make commercial or economic sense does not mean that it must be, by default, a military programme.

Moreover, credible threats of military attack against Iran's enrichment programme have been made or hinted at. Tehran may calculate that, while expensive, having a substantial slice of its capacity immune to attack is like paying for insurance – a cost incurred to reduce risk. Some Iranian sources have said that the purpose of the Fordow-like sites is to provide an invulnerable backup to Natanz, which would make an attack on Natanz less strategically useful since weapons-grade enrichment could take place elsewhere. This makes bombing the large safeguarded civil enrichment plant less attractive, and therefore less likely. That is, the existence of the Fordow sites deters attack on Natanz.

No outside power is threatening to attack Natanz because of its civil applications but because of its bomb-making potential. To deter attack, the Fordow sites must be able to duplicate the capabilities that would be targeted in Natanz. In other words, even if purely civil in mission, the Fordow sites would be sized around a nuclear weapon capability. Current centrifuges are so inefficient that even ten Fordows will have a problem supplying enough fuel-grade uranium for a civilian nuclear reactor, but would be a perfect size for a modest nuclear weapon production.

Iran has already announced intentions to build the new enrichment sites, so they will eventually fall under IAEA safeguards, making the illicit diversion of nuclear material difficult. Nevertheless, the facilities present a dangerous breakout potential. We believe that recent developments still leave some ambiguity about Iran's intentions about building a nuclear weapon, but it is clear that it wants to maintain the potential. A greater enrichment capacity creates a greater danger that, if Iran makes the decision, it can expel IAEA inspectors and start weapons-grade enrichment in hardened underground facilities.

The circumstances surrounding Fordow are worrying. While not a smoking gun, the entire situation has increased suspicions about Iran's intentions. Whether the new sites are intended primarily for civil or military ends, they serve a larger strategic purpose of increasing Iran's future breakout potential in the event it wants to make a run for a nuclear arsenal. If Iran is worried about protecting it enrichment facilities, making political concessions with the IAEA for increased transparency would be more effective in reducing the chances of being bombed than equivocal hardening and dispersal.